Metals

Modelling More Sustainable Aluminium

Kenneth J. Martchek

Alcoa Inc., Alcoa Corporate Center, 201 Isabella Street, Pittsburgh, PA, 15212 USA (kenneth.martchek@alcoa.com)

DOI: http://dx.doi.org/10.1065/lca2006.01.231

Abstract

Goal, Scope and Background. This case study describes the development and utilization of a global, quantitative model of current and projected aluminium and life cycle inventory mass flows. The model and key results were developed to be shared with global aluminium industry technical experts, executives, and external stakeholders to better understand potential paths to more global sustainable aluminium.

Methods. The model is based on annual statistical data since 1950 provided by government agencies and regional aluminum associations and on the most recent life cycle inventory intensity data (year 2002) complied for the global industry by the International Aluminium Institute. Modeling of future aluminium and resource flows are based on literature and industry expert projections of future product shipment demand. The availability of recycle flows to meet these market demands are based on projected utilization, yield, and melt loss recovery rates, post-consumer recycling rates, and anticipated future product lifetimes. The model was developed with quantitative 'what-if' capability to determine the positive impact of enhanced recycling, lower resource intense production, and product usage scenarios.

Results and Conclusion. The model provides the first quantitative assessment of annual global aluminium and life cycle inventory flows. Results include a quantitative estimate by major market of global aluminium product inventory, system losses, recycle rates, and selected resource requirements and air emissions implications.

Recommendation and Perspective. Model results and scenarios have been reviewed and shared with global aluminium technical leaders, executives and key external stakeholders in support of the International Aluminum Institute's new voluntary global objective to better monitor and enhance aluminium recycling and sustainable development initiative.

Keywords: Aluminium; emissions and energy intensity; global resource flows; life cycle management; natural resources; recycling; sustainable management

Introduction

Statistics on the resources flows required to produce primary and recycled aluminium are incomplete on a global basis. In addition, there has not been a consensus or quantitative estimate of future resource flows related to aluminium production or the potential availability of less resource intense end-of-life aluminium (recycled) metal to meet ever increasing consumer and developing nation needs.

1 Goal and Scope

A model was developed by Alcoa Inc. [1] to provide a quantitative understanding of historic and today's (year 1950 through year 2003) worldwide aluminium mass flows and systems losses. In addition, current and future resource requirements and life cycle inventory flows were estimated by coupling these global aluminium mass flows with global, average life cycle inventory intensity data [2] developed from a majority of producers via the International Aluminium Institute (IAI). The model was also developed to provide quantitative scenario development capability to determine the positive impact of enhanced recycling, lower resource intense production, and product usage scenarios. The model and key results information were developed to be shared with global aluminium industry technical experts, executives, and external stakeholders to better understand potential paths to more global sustainable aluminium.

2 Modelling

2.1 Structure

Modeling of historic and current flows was built around Aluminium 'Product Net Shipments' statistical data provided by governments such as the US Geological Survey [3–5] or regional aluminum associations such as the European Aluminium Association, Australian Aluminum Council, the Japan Aluminium Association or the North American Aluminum Association [6]. The data was gathered starting in year 1950 into a comprehensive spreadsheet model by year, by region (European Union, South America, China, etc.), and per the following customer (market) segmentation:

- Building & Construction
- Transportation – Auto & Light Truck, Aerospace, and Other (Heavy Trucks, Trains, etc.)
- Packaging – Aluminium Containers and other Packaging (Foil, etc.)
- Machinery & Equipment
- Electrical – Cable and Other Electrical
- Consumer Durables
- Other (such as aluminum use for propellant or steel deoxidation)

From Product Net Shipments, the model estimates both 'Internal' (runaround) aluminum facility recycle flows and 'New' (prompt, fabricator) customer recycle flow amounts based on estimation of average utilization, yield, and melt loss rates identified in the literature and reviewed and agreed upon by a sub-team of global aluminum technical experts.

Table 1: Example of global average worldwide collection (recycle) rates and melting recoveries by market

	Collection %	Collection %	Melting Recovery %
	1990	2000	
Buildings	69	70	96
Autos & Light Trucks	75	75	96
Aerospace	76	75	96
Other Transport	76	75	96
Containers	61	59	85 (net of 4 cycles/yr)
Packaging – Foil	13	16	30
Machinery	40	44	96
Electrical Cable	45	51	96
Electrical Other	30	33	96
Consumer Durables	20	21	96

This sub-team of experts was commissioned by the IAI Global Aluminium Recycling Committee (GARC). 'Post Consumer' (end of product life) aluminum flows are estimated from Product Net Shipments in previous years, estimated product lifetimes (worldwide by market by year), scrap recollection rates (by region by market by year) and recovery factors again based on industry statistics, published literature, and review and agreement by the IAI GARC committee. An illustration of some of this data on scrap recovery rates and melting recovery efficiency is provided below in **Table 1**.

Modeling of future aluminium and resource flows are based on literature [7,8] and expert projections of life cycle inventory intensity rates [2,9] and aluminium product shipments by market (currently with a weighted average compounded annual growth rate of 2.5% per year.) The availability of recycle flows to meet these market demands are based on projected utilization, yield, melt loss, recovery rates, post-consumer recycling rates, and anticipated future product lifetimes. Primary aluminum production is then calculated to determine the market demand for additional primary capacity and resulting resource requirements.

2.2 Validity checks

There are two 'validity checks' in the model:

1) Comparison of estimated Post-Consumer & New Scrap by year with published values by year. (This check is informational since published values for global recycled metal are considered to be incomplete.)
2) Comparison of the estimated market demand for Primary aluminum by year with published primary production by year.

Fig. 1 shows the aluminum production that is estimated by the model to have been required for the years 1970 to 2003, based on Product Net Shipments less Post-Consumer and New recycle flows and system losses. This is shown to be in fairly good agreement with reported worldwide primary alu-

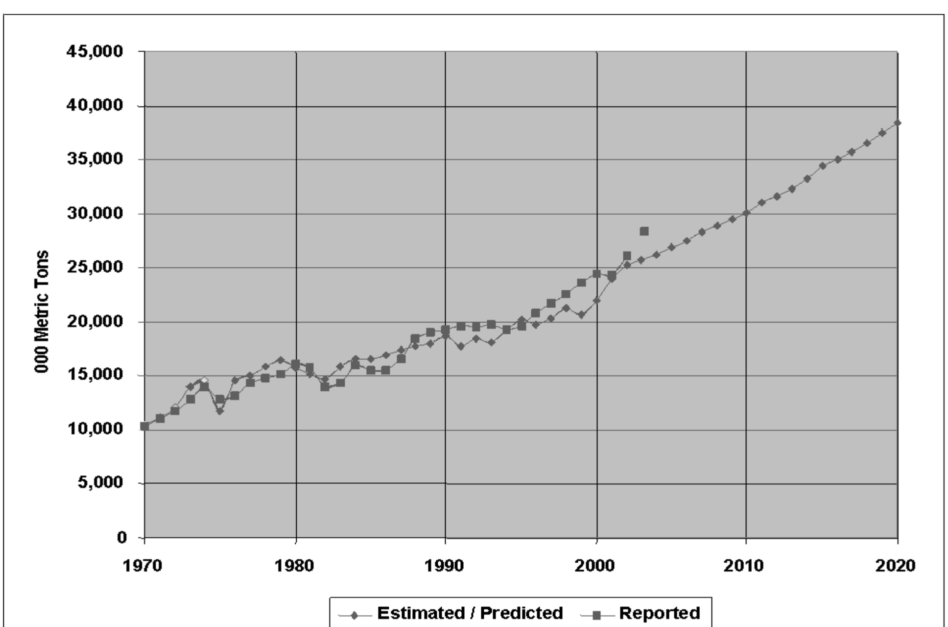

Fig. 1: Estimated vs. reported worldwide primary production

minum production for the years 1970 to 2003. Required primary aluminum production is then projected to the year 2020, with assumptions about each market segments growth rates, post –consumer scrap collection rates, and anticipated recoveries based on latest trends.

3 Key Results

The model's assessment of global aluminium mass flows is shown schematically in **Fig. 2**. The size (area) of the circles illustrates relative volume of flows. In year 2003, recovered post-consumer and new customer recycled metal supplied 33% of the global aluminium industry's product net shipment supply.

An estimated 516 million metrics tons of aluminium, about 73% of all of the aluminium ever produced, is contained in current transportation, cable, and building 'product inventory' (in service) as illustrated in **Fig. 3**. The model also projects future product inventories volumes by market segment to year 2020 also illustrated in Fig. 3.

Additional key results also included system losses such as aluminium packaging lost in landfills or metal oxidized to aluminium oxide when used as a propellant or for de-oxi-

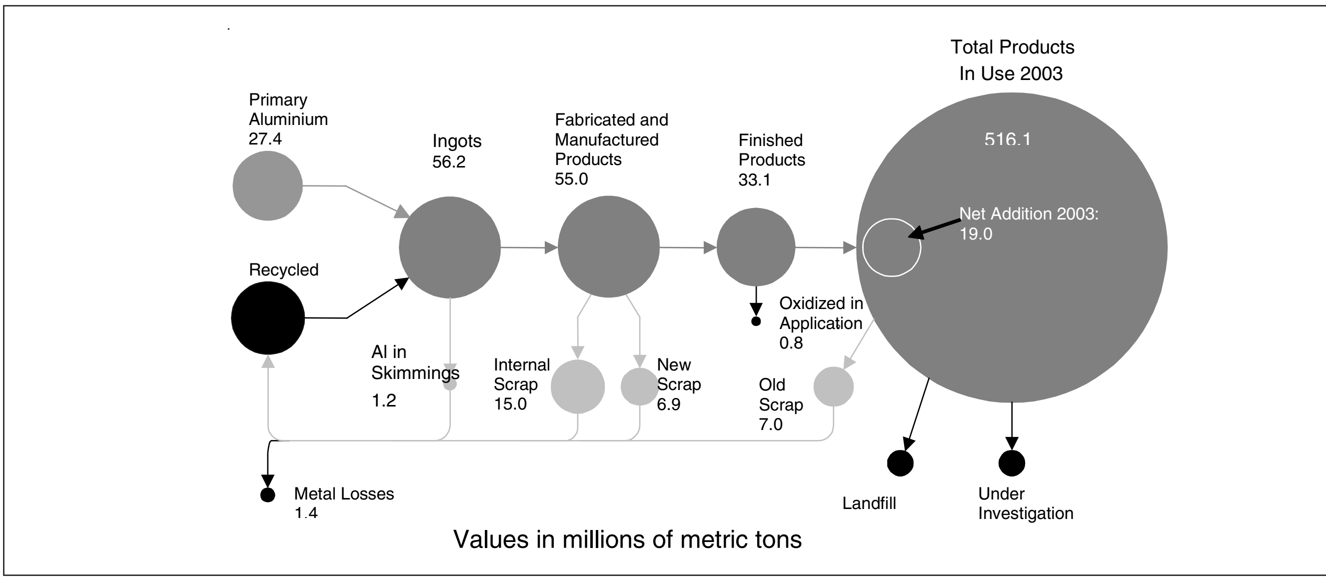

Fig. 2: Global aluminium mass flows for the year 2003

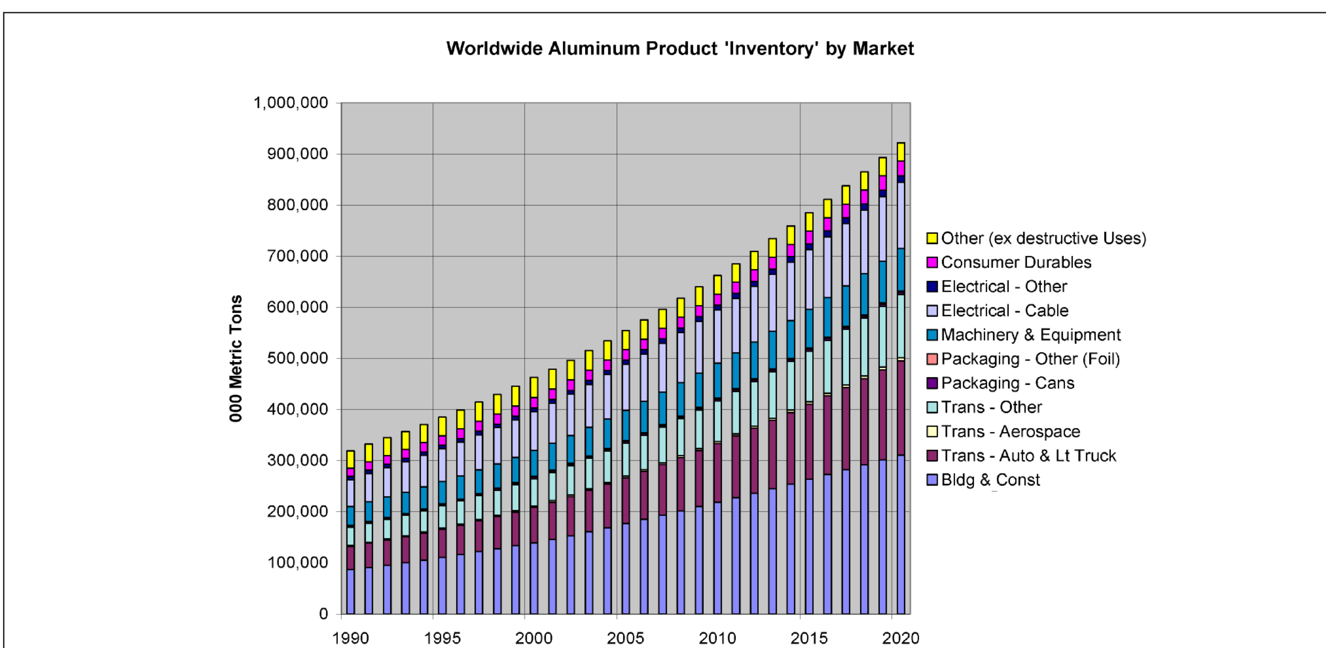

Fig. 3: Worldwide aluminum product 'inventory' by market

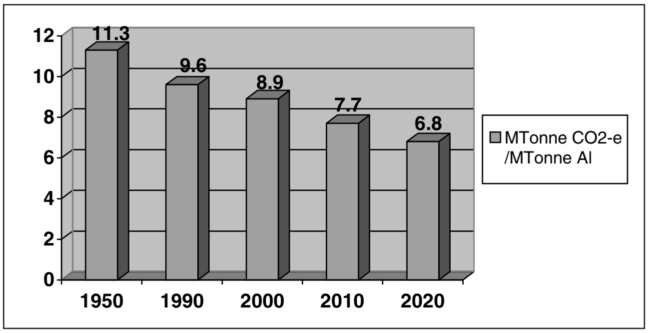

Fig 4: Greenhouse gas emissions intensity of aluminium shipments

dizing steel melts. The model also provides an assessment of past, current, and projected energy and emissions intensity of aluminium semi-fabricated shipments as illustrated in **Fig. 4** based on the latest assessment of average greenhouse emissions intensity for aluminium processes [9].

On average, worldwide aluminum products are becoming less GHG intense on a per ton shipped basis due to two reasons:

1) Increase in the percent recycled metal relative to primary metal (only 5% of the energy and GHG emissions is required to produce aluminium ingot compared to primary (bauxite / Al_2O_3 / electrolysis) aluminum, and
2) Lower emissions from primary aluminum facilities due to reductions in energy intensity and significant reductions in perflurocarbon emissions.

4 Outcomes

The results of the model were initially shared with the Board of Directors of the IAI in May 2004. (The Board is composed of CEOs and senior executives of the world's largest aluminium suppliers.) Model development, the GARC expert review and contribution, and results of global aluminium flow were described including a quantitative assessment of GHG emissions from global industry aluminium facilities today and projected into the future as a guide to the industry's contribution to climate change effects.

At that time, the Board requested a 'what if' case scenario that later indicated that industry factory and indirect emissions from purchased electricity could be stabilized despite significant industry growth by 2020 based on 1) currently projected recycled metal flows, and 2) moving all of the global industry toward today's (2003) global benchmark technologies and operating best practices. Furthermore, the model indicated that fuel efficiency and emissions savings due to additional aluminium transportation products had the potential to surpass the global industry's production emissions by 2020.

In May 2005, addition model results were shared with the IAI Board and they added the following voluntary objective to their list of Sustainable Development quantitative goals in recognition of the ecological and economic value of enhanced recycling to reduce natural resource consumption and life cycle inventory effects:

"The IAI has developed its Sustainability Material Flow Model to identify future recycling flows. The Model projects that global recycled metal supply (back to the industry) will double by 2020 from today's (2005) level of 6.4 million tonnes. The Aluminium Industry will report annually on its global recycling performance."

The IAI continues to develop and improve the model, collect supporting life cycle inventory intensity data, and utilize the scenario capability to quantitatively assess current and future production paths and sustainable strategies.

References

[1] Bruggink PR, Martchek KJ (2004): Worldwide Recycled Aluminum Supply and Environmental Impact Model. In: Tabereaux AT, Light Metals (eds) (2004), Proceedings of the 2004 Annual Meeting, Charlotte, NC, TMS (The Minerals, Metals & Materials Society), Warrendale, Pennsylvania, March 14–18, pp 907–911

[2] International Aluminium Institute (2003): Life Cycle Assessment of Aluminum: Inventory Data for the Worldwide Primary Aluminium Industry, International Aluminum Institute, London, UK, March <http://www.world-aluminium.org/iai/publications/documents/lca.pdf>

[3] Plunkert PA (2001): Aluminum. Minerals Yearbook, US Geological Survey, US Department of the Interior, Reston Virginia. 6.1–6.19 <http://minerals.er.usgs.gov/minerals/pubs/commodity/aluminum/050401.pdf>

[4] Plunkert PA (2002): Aluminum. Minerals Yearbook, US Geological Survey, US Department of the Interior, Reston Virginia. 6.1–6.19 <http://minerals.er.usgs.gov/minerals/pubs/commodity/aluminum/alumimyb02r.pdf>

[5] Plunkert PA (2003): Aluminum. Minerals Yearbook, US Geological Survey, US Department of the Interior, Reston Virginia. 6.1–6.19 <http://minerals.er.usgs.gov/minerals/pubs/commodity/aluminum/alumimyb03.pdf>

[6] Aluminum Association (2003): Aluminum Statistical Review for 2002. The Aluminum Association Inc, Washington, DC

[7] Rombach G (2002): Future Availability of Aluminum Scrap. In: Schneide W (ed), Light Metals 2002. Proceedings of the 2002 Annual Meeting and Exhibition, Washington, DC. TMS (The Minerals, Metals and Materials Society) Warrendale, Pennsylvania, February 17–21, pp 1011–1018

[8] Economics of Aluminium, 8th edition (2003): Roskill Information Services, London, UK

[9] International Aluminium Institute (2000): Life Cycle Inventory of the Worldwide Aluminium Industry with Regard to Energy Consumption and Emissions of Greenhouse Gases, International Aluminum Institute, London, UK, March <http://www.world-aluminium.org/iai/publications/documents/expanded_summary.pdf>

Received: June 17th, 2005
Accepted: October 9th, 2006
OnlineFirst: October 10th, 2005